NDIA System Engineering Division

Integrated Diagnostics Committee

Electronics Prognostics Technology

Task Group

E-Prog II Workshop Day 2

Electronics Prognostics R&D Needs Definition

24 - 25 January 2006

Workshop II Objectives

- To identify the perceived needs of legacy and new weapon systems for electronic prognostics
- To identify common needs across multiple systems
- To draft the key content of S&T, RDT&E and V&V programs that address these common needs
- To assemble these programs into roadmaps for technology development
- To identify the follow-on issues to implement the roadmaps

Workshop Agenda - 25 January 2006

		Workshop Goal
0700	**Registration and Continental Breakfast**	***Accomplishment***
0800	**Day 2 Charge and Breakout**	
0830	**Parallel Sessions to Consolidate Needs**	
	• **Current R&D Applicability**	***Develop Roadmaps***
	• **S&T Program Needs - T. Galie (HM)**	***Consolidate Roadmaps***
	• **RDT&E Program Needs - J. Kelly, M. Hollins**	***Program Elements***
	• **V&V Program Needs - P. Dussault, C. Wenrick**	
1000	**Break**	
1030	**Roadmap Key Program Layout and Presentation Preparation**	***Layout Roadmaps***
1230	**Lunch**	
1330	**Summarize Workshop Results**	***Summarize Results***
	• **Identify Key Issues**	***Establish Product Schedules***
	• **Next Steps for IPT to Address**	
	• **Roadmap Completion Schedule**	
	• **Final Report Development Schedule**	
1530	**Adjourn**	

January 25th Session Format

4 parallel sessions covering specific topics with a mix of people from day 1 sessions

Goal is to have representation from all day 1 sessions in each day 2 session

- **Session 1 - Current R&D applicability**
- **Session 2 - S&T Program Needs**
- **Session 3 - RDT&E Program Needs**
- **Session 4 - V&V Program needs**
- **Results will then be integrated at afternoon sessions**

General Topic Areas

- Power Supplies
- High Power Electronics
- Cabling and connectors
- Digital
- Software

Discussion Topics

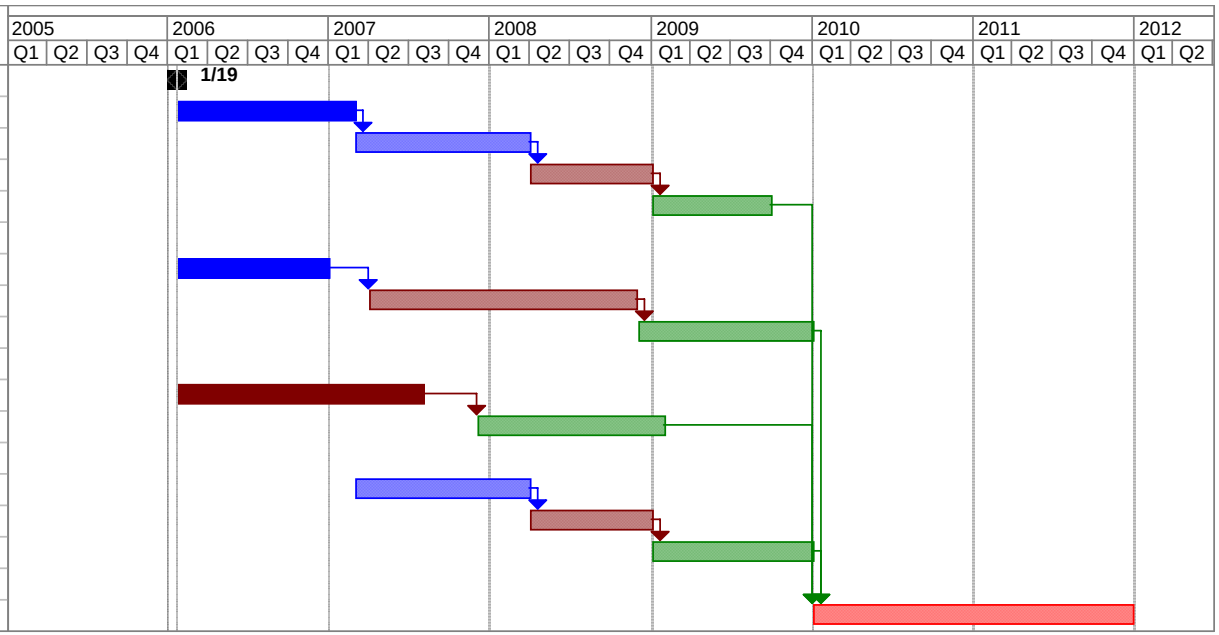
- Known S&T in the technology area
- New S&T needed to address area
- S&T that is ready for transition to system demonstration
- How to do V&V for military systems

Electronics Prognostics Roadmap Template

Session Topic	S&T
Technology Area	Digital Electronics
Program1 N=new E=Existing	Topic N / E Funding Duration
Program2	Topic N / E Funding Duration
Program3	Topic N / E Funding Duration
Program4	Topic N / E Funding Duration
Program5	Topic N / E Funding Duration
Comments	

Basic Roadmap Using MSProject

ID	Task Name
1	**Power Electronics Technology**
2	**S&T1**
3	**NS&T1**
4	**NRDT&E1**
5	**NV&V1**
6	
7	**S&T2**
8	**NRDT&E2**
9	**NV&V2**
10	
11	**RDT&E1**
12	**NV&V1**
13	
14	**NS&T2**
15	**NRDT&E3**
16	**NV&V4**
17	
18	**Integrated System Application**

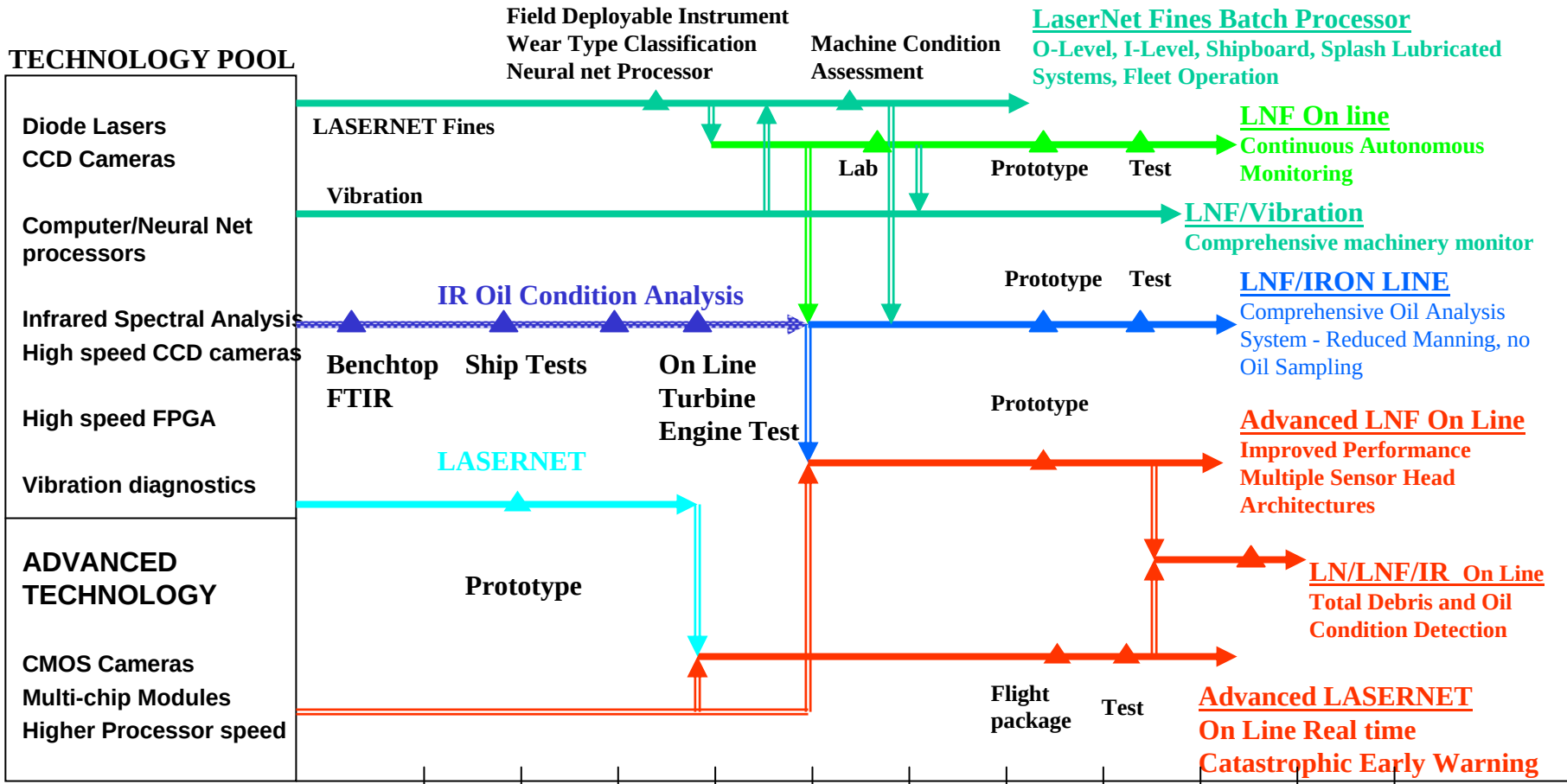


Funding ($) 1.5M 2.5M 3.2M 2.1M 8M

Blue= S&T, Maroon=RDT&E, Green=V&V, Red=Implementation

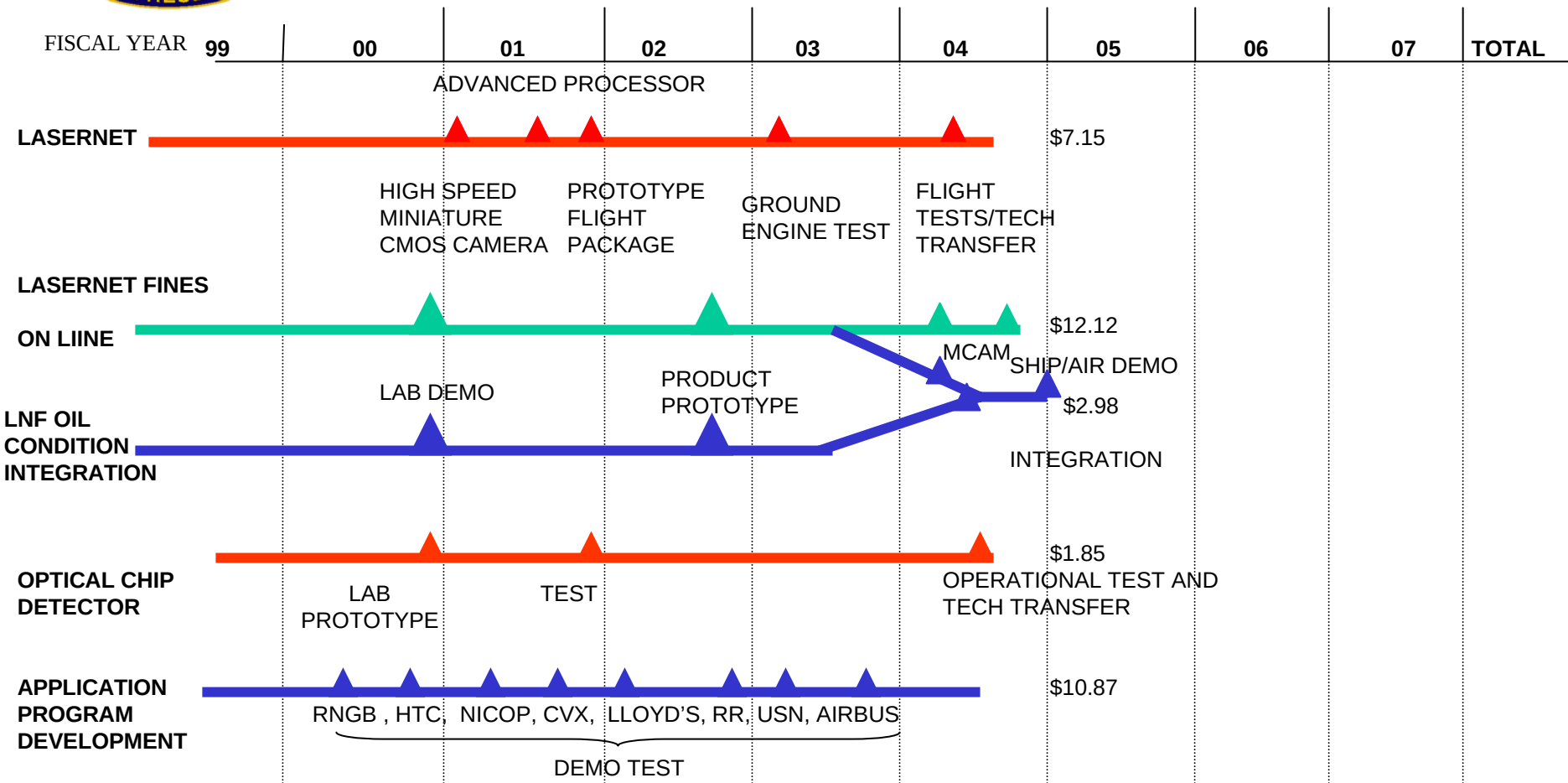
Solid Color=existing program, cross hatched color=new programs

LASERNET TECHNOLOGY DEVELOPMENT PATH



CALENDAR YEAR	95	96	97	98	99	00	01	02	03	04	05
REQ TO EXECUTE PLAN ($ M)	1	1.3	1.5	1.2	1.58	2.6	3.52	6.74	6.8	5.6	3.5
US NAVY ($ M)											
ONR	1	1.3	1.5	1.2	1.5	2.2	2.6	4.0	4.1	3.4	3.0
ADVANCED PROGRAMS (CVX)						.2	.7	2.64	2.5	1.9	.3
FOREIGN MILITARY SUPPORT	0	0	0	0							
S&T					.08	.08	.1	.1	0.2	.3	.2
ADVANCED PROGRAMS						.12	.12				
						research	development/test			acquisition	

LASERNET MACHINERY MONITORING TECHNOLOGY PROGRAM



	99	00	01	02	03	04	05	06	07	TOTAL
TOTAL FUNDING		6.2	6.9	10.12	7.25	3.5	.6	.3	.1	34.97
SOURCES										
ONR TOC		5.46	5.8	7.28	4.55	1.4	.3	.3	.1	25.19
OTHER US (CVX)		.2	.7	2.64	2.5	1.9	.3			8.24
UK		.544	.396	.2	.2	.2				1.54

NAVAIR S&T

Title	Firm
Techniques and Prognostic Models to Relate Useful Life Remaining and Performance Life Remaining Predictions to Detectable Fault Conditions in Electronic System Power Supplies	SoHaR Incorporated
Assessing Useful Remaining Life of Lithium (Li)-Ion Batteries After Deep Discharges	Yardney Technical Products, Inc.
Advanced Fault and Failure Anomaly Detection Technologies to Support Enhanced Prognostics and Health Monitoring (PHM) Capabilities	Ridgetop Group, Inc.
Techniques and Prognostic Models to Relate Useful Life Remaining and Performance Life Remaining Predictions to Detectable Fault Conditions in Electronic System Power Supplies	Ridgetop Group, Inc.
Techniques, Processes, and Tools for Managing the Relationship between Diagnostic and Prognostic Capabilities as Applied to Health Management Systems	Scientific Monitoring, Inc.
Techniques, Processes, and Tools for Managing the Relationship between Diagnostic and Prognostic Capabilities as Applied to Health Management Systems	ALPHATECH, Inc.
Intelligent Embedded Diagnostic System for Future Avionic Systems	Impact Technologies, LLC
Techniques and Prognostic Models to Relate â€œUseful Life Remainingâ€ and â€œPerformance Life Remainingâ€ Predictions to Detectable Fault Conditions in Flight Control Actuators	Impact Technologies, LLC
Advanced Fault and Failure Anomaly Detection Technologies to Support Enhanced Prognostics and Health Monitoring (PHM) Capabilities	Impact Technologies, LLC
Techniques and Prognostic Models to Relate Useful Life Remaining and Performance Life Remaining Predictions to Detectable Fault Conditions in Electronic System Power Supplies	Impact Technologies, LLC
Advanced Fault and Failure Anomaly Detection Technologies to Support Enhanced Prognostics and Health Monitoring (PHM) Capabilities	Intelligent Automation, Inc.
Intelligent Embedded Diagnostic System for Future Avionic Systems	Williams-Pyro,Inc.

Current R&D Activities

PROJECT TITLE	STATUS	DURATION	AMRDEC POC
PROG/DIAG FOR FUTURE FORCE (ATO)	FUNDED	FY 04-08	STEPHEN MAROTTA, 256-876-9283
NEURAL NETWORK RELIABILITY PROGNOSTICS TOOL (SBIR)	FUNDED	FY02-05	WYATT SHANKLE, 256-313-6379
UAV DIAGNOSTICS/PROGNOSTICS (SBIR)	FUNDED	FY 05	WYATT SHANKLE, 256-313-6379
SOLDER INTERCONNECT PREDICTOR	FUNDED	FY 05-06	WYATT SHANKLE, 256-313-6379
TECH COORD GRP FOR PREDICTIVE MATERIALS AGING AND RELIABILITY	FUNDED	FY 05-09	WYATT SHANKLE, 256-313-6379
VIRTUAL SENSORS FOR STATE MEASUREMENTS, HEALTH & USAGE MEASUREMENTS, AND LOAD ESTIMATION	FUNDED UNDER SARAP	FY 03-06	NED CHASE, 757-878-3025
AFFORDABLE HEALTH AND USAGE MONITORING SYSTEM FOR UNMANNED AERIAL VEHICLES	PHASE I FUNDED PHASE II PROPOSED	FY 04-07	TREVEN BAKER, 757-878-0155
CORROSION AND CORROSIVITY MONITORING SYSTEM	FUNDED	FY 02-05	TREVEN BAKER, 757-878-0155
INTEGRATED OIL DEBRIS AND CONDITION SENSOR	FUNDED	COMPLETED	TREVEN BAKER, 757-878-0155

Current Unfunded R&D Activities

PROJECT TITLE	STATUS	DURATION	AMRDEC POC
UAV CBM THRU DIAGNOSTICS AND PROGNOSTICS	UNFUNDED	FY 06-08	WYATT SHANKLE, 256-313-6379
DIAG/PROG ALGORITHMS FOR ENABLING ELECTRONIC COMPONENT CBM	UNFUNDED	FY06-10	ROBERT RUSSELL, 256-842-2767
DEMO OF MANPOWER REDUCTION USING CONTINUOUS CBM OF ELECTRICAL AND WIRING SYSTEMS	UNFUNDED	FY 05-06	WARREN ALFORD, 256-313-6498
EMBEDDED CBM SYS AND DATA-LINK FOR ROTARY WING AIRCRAFT	UNFUNDED	FY 06-07	WARREN ALFORD, 256-313-6498
PORTABLE ELECTRICAL SYS CBM BASED TROUBLESHOOTING	UNFUNDED	FY 06-07	WARREN ALFORD, 256-313-6498
EMBEDDED SENSOR TECH FOR ELECTRICAL CONDUCTIVE PATH AND SYSTEMS	UNFUNDED	FY 06-08	WARREN ALFORD, 256-313-6498

Post Workshop II Tasks to Complete Effort

- **Format workshop results into actionable plan and investment roadmap**
- **Establish funding sources, transition paths and sponsors**
- **Implement an Electronic System Prognostic - Implementation Initiative (ESP-I^2)**
- **Prepare and deliver workshop final report**

NDIA System Engineering Division
Integrated Diagnostics Committee

Submarine Platform Electronics Prognostics Needs
E-Prog II Workshop

Mandeep Nehra
Code 1554
NAVSEA Undersea Warfare Center
Newport, RI
Jan 20, 2006

Submarine E-prog Requirement

Weapon System and Application	TA Handling Systems: OA-9070, OK-276, Next generation handler Principal goal: Improve at-sea reliability, uptime, reduce unsched maintenance costs (overseas, diver, dry dock)
E-Prog Need Details	•Mechanical and electrical prognostics – Prediction Horizon: 2-4 weeks / 75% confidence – Account for LDT – ship schedule, part availability lag time – willing to settle for 75% confidence given current failure criticality
Current Development Program Elements	•S&T – performance data collection ongoing, 2000+
Current S&T and RDT&E Applicability	•S&T – physics models, @NUWC, sponsored by PMS401 2006-2007 •R&D –Determine if there is inherent capability in the exiting electronics components
S&T and RDT&E Needs and Development Program Timelines	•S&T – 2007 - 2009 – condition sensing/detection technology – degradation/failure models – prognostics algorithms •RDT&E – demonstration on military system, NGH, 2009

Submarine E-prog Requirement

Weapon System and Application	Sonar Systems: BQQ-10, VA Class Navigation Radar : BPS-15 SSBN, BPS-16 VA Propulsion control
E-Prog Need Details	•COTS, Electronics prognostics –Prediction Horizon: 1 week / 90% confidence –Power Supplies – specialized CCAs
Development Program Elements	•S&T – limited performance data collection, "proprietary"
Current S&T and RDT&E Applicability	•S&T – a priori work at contractors, COTS vendors? –Provide access to data on current test systems –Bit standards –API framework
S&T and RDT&E Needs and Development Program Timelines	•S&T – ongoing AP Build incorporation thru 2012 – looking for apriori performance information to supplement data collection, sensing/detection – existing failure models – prognostics algorithms •RDT&E – demonstration on military system builds thru 2012 •Integration with other condition management systems

Submarine E-prog Requirement

Weapon System and Application	Arrays: SSN, SSBN TB-33, TB16NG, TB16G, fiber degradation, Laser assemblies Principal goal: OOM improvement in at-sea reliability, reduce unscheduled maintenance costs
E-Prog Need Details	•Acoustic electronics, optics prognostics – Prediction Horizon: 1 week / 75% confidence •Mechanical, FO prognostics – Prediction Horizon: 1-2 weeks / 75% confidence
Development Program Elements	•S&T – Limited performance and test data collection – Physics based models @NUWC, PMS401 2006-2007 –Instrumented measurement of: handler impact; operational stress @NUWC, PMS401, 2005-2007
Current S&T and RDT&E Applicability	•No known work in this area
S&T and RDT&E Needs and Development Program Timelines	•S&T – impact TB33 development, 16 upgrades – FO degradation models 2006 – 2007 – laser electronics measurement –sensing/detection techniques 2006-2007 •RDT&E – demonstration on military system 2009

Submarine E-prog Requirement

Weapon System and Application	UUVs Principal goal: improved at-sea reliability, reduce
E-Prog Need Details	•Power system condition •Control, sensor electronics prognostics –Prediction Horizon: 1 week / 75% confidence •Mechanical prognostics – Prediction Horizon: 1-2 weeks / 75% confidence
Development Program Elements	
Current S&T and RDT&E Applicability	
S&T and RDT&E Needs and Development Program Timelines	•S&T – ongoing development 2000-2010 – performance data collection – sensing/detection techniques – failure models •RDT&E – demonstration on military system

Submarine E-prog Requirement

Weapon System and Application	Type 18 Periscope VLS Launcher: SSN Principal goal: Improve at-sea uptime, reduce unsched maintenance costs
E-Prog Need Details	•Control, sensor electronics prognostics –Prediction Horizon: 1 week / 75% confidence •Mechanical prognostics – Prediction Horizon: 2-4 weeks / 75% confidence
Development Program Elements	•Map subsystem criticality and failure modes •Map existing subsystem BIT that could be accessed and stored externally to develop a data base for prognostic driven logistics •Map s/w leakage and trac s/w undefined state to logistic statistics
Current S&T and RDT&E Applicability	•Development of both behavior based and fuzzy logic autonomy for hazard avoidance
S&T and RDT&E Needs and Development Program Timelines	•S&T – impact existing inventory – performance data collection – sensing/detection techniques – failure models – prognostics algorithms •RDT&E – demonstration on military system

Carrier and Surface Ship E-prog Template

Weapon System and Application	C5I (Command, Control, Communications, Computer, Combat and Information) Systems
E-Prog Need Details	•Prediction horizon could be in hours or days depending on the mission and will vary with mission •Confidence levels need to be established
Development Program Elements	•Must support Fleet needs metrics – right timed maintenance (if we can predict when it will fail, we can replace it at the most opportune time) – decreased requirement for onboard sparing – decreased time requirements for troubleshooting (less stress on maintenance infrastructure) •Must promote a remote monitoring sustainment philosophy freeing sailors to focus on operations and the shore community on maintenance and logistics
Current S&T and RDT&E Applicability	•None know to Fleet •Fleet needs to be informed about BIT diagnostic and prognostics capabilities inherent in commercial systems to drive requirements to the Program Offices
S&T and RDT&E Needs and Development Program Timelines	•LCS (IOC 2007, V&V 1year) •DDX (IOC 2012, V&V 5 years) •Legacy ships –Implement BIT capabilities inherent in commercial components –spiral development and insertion starting in FY07 based on component criticality based on the mission dependency algorithms deployed in support of DRRS

Ships' Surface Ship E-prog Template

Weapon System and Application	DDX – Integrated Power Systems (IPS)
E-Prog Need Details	•High power switching electronics prognostics –What are the failure mechanisms and how can you sense them? •What are the critical systems and what arequierments are needed for advanced diagnostics and prognostics
Development Program Elements	•Must work with power semi conductor manufacturers •Must work with universities on advanced algorithms •Must be able to acquire and analyze data •Must work with fleet to analyzed faults •Must report through MRSS and incorporate ICAS
Current S&T and RDT&E Applicability	•Advanced sensor research including fiber optic current, voltage, temperature, and stress/strain. •Partial discharge sensors to monitor for insulation breakdown •Semiconductor manufacturers are researching failure and prognosis on device level
S&T and RDT&E Needs and Development Program Timelines	•How can competitors be encouraged to work together and share information •A system perspective must be maintained •Must be able to test hardware and software on ship equivalent systems •DDX (IOC 2012, V&V 5 years)

Surface Ship E-prog Template

Weapon System and Application	Unmanned Surface Vehicles (USVs)
E-Prog Need Details	•Electronic Prognostics needed for 20 hr missions •Insertion of Intelligent Autonomy for Integrated Ship Health Management (ISHM) to process sensor input in the context of the Vehicle Health State (fuel, power, mission-driven path planning, environmental history, subsystem s/w and h/w and component petigree/burnin)
Development Program Elements	•Map subsystem criticality and failure modes •Map existing subsystem BIT that could be accessed and stored externally to develop a data base for prognostic driven logistics •Map s/w leakage and trac s/w undefined state to logistic statistics
Current S&T and RDT&E Applicability	•Development of both behavior based and fuzzy logic autonomy for hazard avoidance
S&T and RDT&E Needs and Development Program Timelines	•Embedded BIT for training and health monitoring of subsystems

Carrier and Surface Ship E-prog Template

Weapon System and Application	•HME Control and Monitoring Networks and Cargo and Weapons Handling Systems –Secondary/backup power supplies –Network switches –Server Blades
E-Prog Need Details	•Prognostic needs for ships have not been evaluated
Development Program Elements	•Base development on inherent capabilities of commercial components •Determine how to implement prognostic capabilities that are available for same components in industry
Current S&T and RDT&E Applicability	•Adapt Sun Microsystems techology
S&T and RDT&E Needs and Development Program Timelines	•No work in this area yet but lower manning and ship skill sets require immediate attention

Prognostics Must Provide Fleet Dividends

- Must offset loss of shipboard logistics and maintenance capabilities resulting from
  - reduced manning ships (less technician hours for preventive and corrective maintenance)
  - reduced OPTAR (less ability to stock and use spare parts)
  - higher OPTEMPO (less available "down hours" for systems)
  - more operators, less maintainers (pipeline training not as robust as it used to be with regards to electronic troubleshooting)
  - reduced shore infrastructure and maintenance budgets (less travel, fewer techs)

Issues To be Addressed

- Mission criticality of redundant Systems, equipment, and components
- Establishment of equipment and component failure and usage data reservoirs and establishment of protocols and agreement to enable multiple vendor access
- Policy, procedures and standards to encourage and facilitate development of APIs to access existing commercial electronic component BIT data
- Stand-up of Fleet and Acquisition Program POCs/Champions for electronics prognostics
- A new contract philosophy is needed to encourage cross vendor sharing of intellectual property (no freebees…agreements and compensation guidelines)
- Ship acquisition offices design to readiness and availability requirements and, therefore, cannot justify incorporation of prognostics even though it may be written into the requirements documents

FCS

Weapon System and Application	FCS will be forwarded later pending approval via ID chairs. Cliff Wenrick.
E-Prog Need Details	(will also be setting up Prognostics Team intra-FCS)
Development Program Elements	
Current S&T, RDT&E and V&V Applicability	FCS will integrate with current and future force prognostics/
S&T, RDT&E and V&V Needs and Development Program Timelines	

Army IETM interface

Weapon System and Application	Tactical Light, Medium, Heavy Systems(MSD based ietms)(Army)
E-Prog Need Details	Coordinate progn diagn needs with ietm/msd; I.e maintainer connection
Development Program Elements	
Current S&T, RDT&E and V&V Applicability	
S&T, RDT&E and V&V Needs and Development Program Timelines	Ongoing, TACOM next gen ietm software EMS 06 ; not all vehicles will migrate.

Stryker

Weapon System and Application	Stryker Powerpack (caterpiller/allison) limited vendor data support
E-Prog Need Details	Access; how do you provide assurance that proprietary data is protected yet usable.
Development Program Elements	BIT added after design; added at 3rd Brigade level. Institutional limits to diagnosis to LRU level; capable of
Current S&T, RDT&E and V&V Applicability	Continuous testing/dedicated; some prognostics efforts in comm equip.

FMTV

Weapon System and Application	FMTV (Stewart-Stevenson)
E-Prog Need Details	Interested in prognostics diagn.
Development Program Elements	
Current S&T, RDT&E and V&V Applicability	Next gen vehicle 07; cost a factor; but what is out there; what is possible?
S&T, RDT&E and V&V Needs and Development Program Timelines	

FTTS

Weapon System and Application	Prognostics and diagnostic on generator sets (future tactical transport system)
E-Prog Need Details	Interested in prognostics diagn.and how is this data made meaningful
Development Program Elements	
Current S&T, RDT&E and V&V Applicability	Need basic research and algorithms.
S&T, RDT&E and V&V Needs and Development Program Timelines	

More FCS

Weapon System and Application	Aberdeen doing extensive sw v&v planning
E-Prog Need Details	
Development Program Elements	V&V plan in 06. for prog and diag software on the FCS. Actual testing FY07
Current S&T, RDT&E and V&V Applicability	
S&T, RDT&E and V&V Needs and Development Program Timelines	

ARL

Weapon System and Application	Temp humidity, vibration, shock miniturized sensors for munitions. ROI could be up to 65% in future munitions.
E-Prog Need Details	May be open source to other DoD entities.
Development Program Elements	
Current S&T, RDT&E and V&V Applicability	More assets; need more insertion opps from field users. Sustainability maintainability, survivability;
S&T, RDT&E and V&V Needs and Development Program Timelines	

Tracked Vehicles

Weapon System and Application	M88-A2,Bradleys, Paladins, M113,FCS
E-Prog Need Details	Interested in prognostics diagn. And to see what is possible
Development Program Elements	
Current S&T, RDT&E and V&V Applicability	Research in progress.
S&T, RDT&E and V&V Needs and Development Program Timelines	

EFV

Weapon System and Application	Expeditionary Fighting vehicle
E-Prog Need Details	CBM postponed by ONR due to funding constraints Warnings, Cautions and Advisories • Built-in-Test • Third Echelon Test System • ONR Condition Based Need driven maintenance; minimum maintenance.
Development Program Elements	
Current S&T, RDT&E and V&V Applicability	Research in progress.
S&T, RDT&E and V&V Needs and Development Program Timelines	Will be resuming CBM efforts in the 2007-2008 timeframe.

comment

Weapon System and Application	DRS sees lack of data sharing between ATE and vehicle;physics of failure; common modeling techniques at the vehicle level lacking
E-Prog Need Details	Cost benefit tradeoff across when it would be cost effective to pursue different approaches for prognostic
Development Program Elements	1Sensor vice physics of failure 2Data mining of sensor data 3Statistical mining of data1
Current S&T, RDT&E and V&V Applicability	
S&T, RDT&E and V&V Needs and Development Program Timelines	

Weapon System(s) and Application	Rotary Wing Aircraft Electro-Optical Systems, Computers/Processors, Displays, RADAR ,Flight Controls, FADEC, Electro-mechanical Interface, Power Supplies/Power Source, Wiring/Interconnect
E-Prog Need Details	– 24 hours / 95% confidence
Development Program Elements	• S&T – sensing/detection techniques – External/integrated stimulus/testing – physics of failure models – Prognostics algorithms/reasoning • RDT&E – demonstration on military system • V&V – Field Testing and Evaluation
Current S&T and RDT&E Applicability	• reasoning models • Data capture
S&T and RDT&E Needs and Development Program Timelines	• yesterday! • Development Program Through V&V 4 years

Weapon System and Application	All – Technology demonstration/transition
E-Prog Need Details	Need vehicle to increase technology readiness to TRL 6.
Development Program Elements	
Current S&T and RDT&E Applicability	There are a number of promising technologies that are searching for a vehicle to perform proof of concept testing.
S&T and RDT&E Needs and Development Program Timelines	Near term

Weapon System and Application	All – Systems engineering approach to creating verifiable requirements
E-Prog Need Details	Two missions +/- one mission with 60% to 90% confidence
Development Program Elements	
Current S&T and RDT&E Applicability	Current RDT&E programs have no numerical targets for design and test
S&T and RDT&E Needs and Development Program Timelines	

Weapon System and Application	All – Power supply, Analog subsystems, RF subsystems, digital subsystems
E-Prog Need Details	
Development Program Elements	S&T - sensing and detection techniques - Prognostic models/algorithms RDT&E - Simulation/Demonstration in lab V&V – Field testing, evaluation, and algorithm refinement
Current S&T and RDT&E Applicability	
S&T and RDT&E Needs and Development Program Timelines	

Weapon System and Application	All – requirements flowdown
E-Prog Need Details	Prognostics must be pushed to lowest level of design.
Development Program Elements	
Current S&T and RDT&E Applicability	
S&T and RDT&E Needs and Development Program Timelines	